NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

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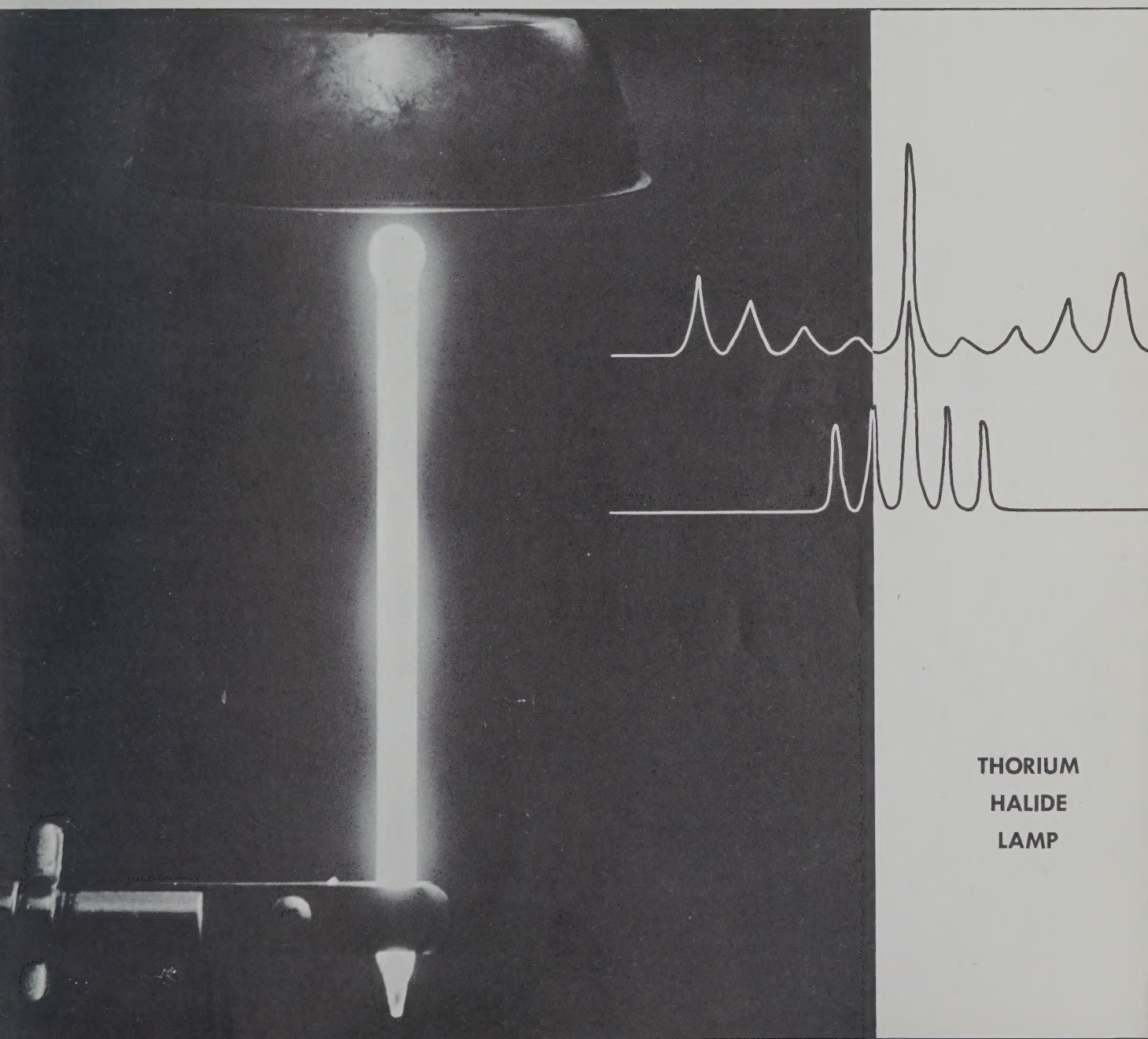

THORIUM
HALIDE
LAMP

· U.S. DEPARTMENT OF COMMERCE FREDERICK H. MUELLER, *Secretary*

NATIONAL BUREAU OF STANDARDS A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS

Technical News

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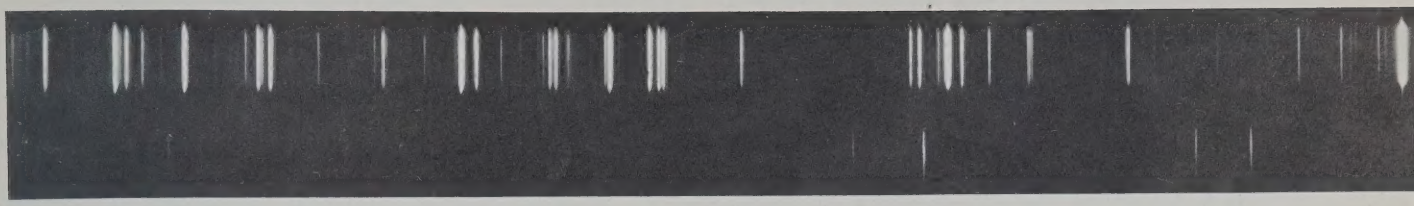
COVER: An electrodeless thorium halide lamp, developed at the Bureau, glows in a microwave discharge. The spectrum of thorium, represented in part by the oscilloscope tracing to the right of the lamp, is expected to provide a good secondary standard for measuring wavelengths in unknown spectra.

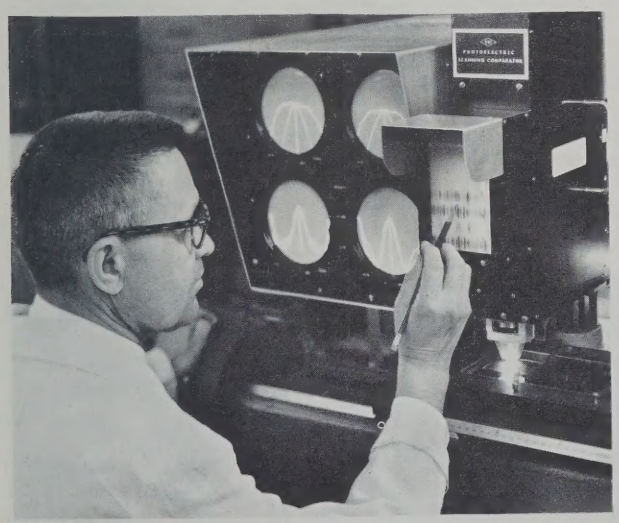
The Spectrum of Thorium:



New Secondary Standards of Wavelength

A DESCRIPTION of the spectrum of thorium containing 15,121 lines—more than twice as many as previously published—has been recorded at the Bureau. This description is the most complete thus far obtained using concave grating spectrographs. The present investigation,[1] conducted by R. Zalubas of the spectroscopy laboratory, yielded about 200 new energy levels. The stronger thorium lines at approximately equal intervals were also measured interferometrically[2] and are being used as secondary standards with which to compare wavelengths of unknown spectra.

The thorium spectrum has come into use as a new secondary standard because its lines are sharp and because its stronger lines are about evenly distributed throughout the range from 2000 to 12000 A. Also, the lines have relatively small Doppler widths and are entirely free from hyperfine structure or isotopic shifts. Improved descriptions of complicated rare earth spectra such as the spectrum of thorium were made possible by the recent development of electrodeless metal-halide lamps at the Bureau's spectroscopy laboratory.



An improved photoelectric scanning comparator, designed and constructed at the Bureau, greatly decreases the time required for measurement of complex unknown spectra. R. Zalubas visually compares lines of known and unknown spectra on the viewing screen, while the oscilloscope screens present curves of line density versus wavelength for four spectra recorded on one plate. Position on the plate, intensity, and shape of the line are recorded by punch-card equipment.

Sample of the thorium spectrum (above) shown beside the iron spectrum. Note that strong thorium lines are uniformly distributed through the region, whereas iron lines of proper intensity for comparison are infrequent.

Since 1888 the iron arc spectrum has been used as a scale of wavelength for the measurement of other spectra. In the past 70 years, many iron lines have been measured interferometrically with respect to the red line of cadmium—the primary standard—and these iron lines have become recognized as international secondary standards of wavelength. In 1955, theoretically calculated wavelengths from well-established energy levels of iron were recommended for standards. Since iron lines are relatively broad, however, they are inadequate for the measurement of spectra of heavier elements or of molecules, which emit much sharper lines than those of iron. Also, iron lines are not evenly distributed in the photographic region of the spectrum. The spectrum of thorium, one of the heaviest naturally occurring elements, offers a solution to these difficulties.

As early as 1926, work on thorium spectra was initiated at the Bureau by C. C. Kiess,[3] but the results were never published. Kiess secured some spectrograms of arcs and sparks between thorium metal electrodes in air using a Hilger prism spectrograph having a dispersion of 0.6 A/mm at 2200 A. He measured some of these spectrograms and the results are included in the present work.

Work on the thorium program was resumed at the Bureau in 1955 by R. Zalubas when electrodeless halide lamps became available as sources for spectrographic studies. These lamps, containing ThI_4 or $ThBr_4$, are excited by microwaves at 2,450 Mc to emit much sharper and more numerous lines than do conventional arcs in air, and the lines are free from reversals. The lamps do not excite the troublesome atmospheric bands that mask particular regions of the spectrum when arcs are used.

Spectrographs having concave gratings with 7,500, 15,000, and 30,000 lines/in. were used in the

present investigation. At least three and as many as eight plates in every region were obtained and measured. Most of them were measured by "hand and eye," but later some were measured by recently available semiautomatic equipment,[1] which permits analysis of complex unknown spectra within a reasonable time.

Zeeman patterns[5] of Th I and Th II were produced using an electromagnet with fields of about 37,000 oersteds. About 1,000 Zeeman patterns were measured and the resulting magnetic splitting factors (g-values) were determined.

Lines of Th I, Th II, and Th III were separated using the following criteria: Relative intensities of lines from lamp and spark exposures, relative intensities of components normal and parallel to the field of unresolved Zeeman patterns as compared with an exposure not under the influence of a magnetic field, resolved Zeeman patterns, and known classified lines of Th I, Th II, Th III, and Th IV.

The relative line intensities are employed as one criterion for separation because, in most cases, Th I lines are relatively stronger in electrodeless lamp exposures than in spark exposures; Th II lines are relatively weak in lamp exposures and stronger in spark exposures; and Th III lines are either not present or are very weak in lamp exposures, but are relatively strong in spark exposures.

Simultaneously with the present work, Meggers and Stanley[2] of the Bureau made interferometric measurements of thorium secondary standards in the region of wavelengths from 3287 to 6989 A. Their results were used to improve the accuracy of the thorium line measurements.

The Bureau's description of the spectrum of thorium should meet all the present requirements for spectrochemistry and for an extension of the structural analysis of the first and second spectra of thorium between the wavelengths of 2000 and 12000 A. Interferometric measurements of more thorium lines are being made by Littlefield at King's College in England and by Stanley at Purdue University at Lafayette, Ind. The Vatican Observatory in Rome is preparing a map of thorium spectra. Work on the analysis of Th I is continuing at the Bureau; a short account of the present state of analysis has been published.[6]

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[1] *For further information, see* A new description of thorium spectra, *by Romuald Zalubas, NBS* Mono. *17 (1960). For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Price 65 cents.*

[2] Wavelengths from thorium-halide lamps, *by William F. Meggers and Robert W. Stanley, J. Research NBS* **61,** *95 (1958).*

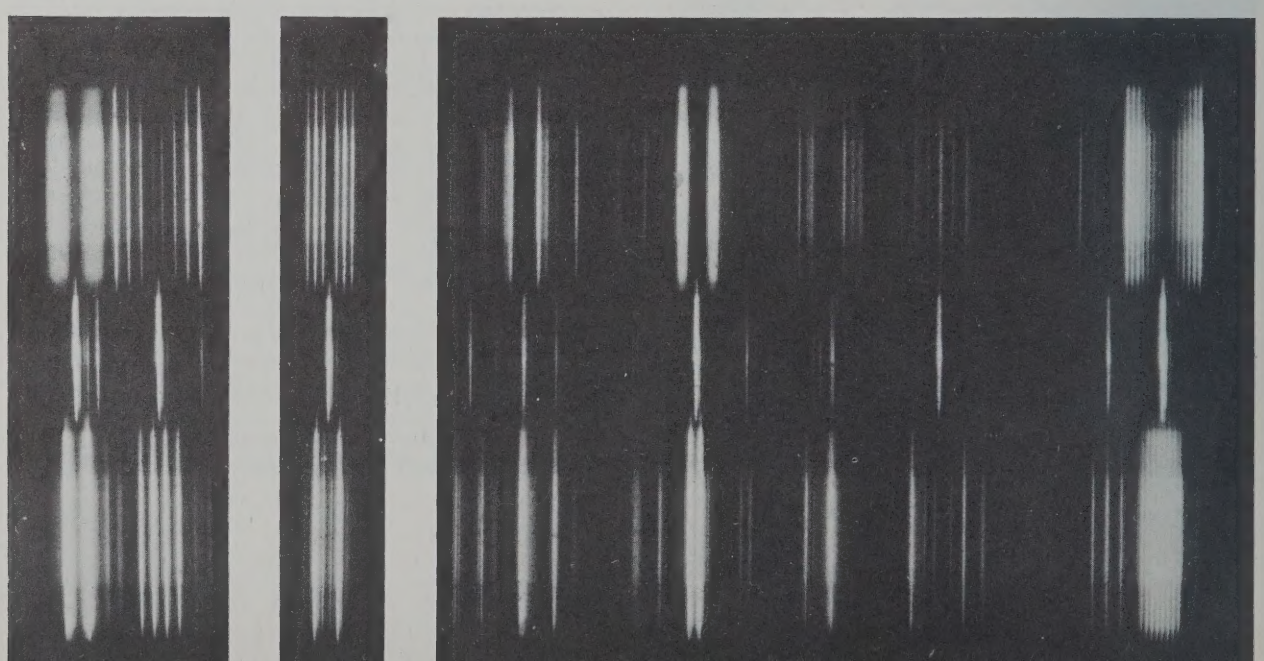
[3] A description and analysis of the first spectrum of thorium, *by R. Zalubas, J. Opt. Soc. Am.* **49,** *512 (1959).*

[4] A scanning photometer for reading spectrographic plates, *NBS Tech. News Bull.* **44,** *93 (1960).*

[5] *According to the simple classical theory of the Zeeman effect, an observer receiving light perpendicular to the magnetic field sees one or more central components polarized parallel to the field and on either side the same number of components polarized perpendicular to the field. Two lines exhibit the same Zeeman pattern if they belong to the same spectral series, or if they are members of different series (e.g., principal and sharp) which arise from similar term combinations, or if they belong to analogous series occurring in different spectra.*

[6] A preliminary list of levels and g-values for the first spectrum of thorium (Th I), *by Romuald Zalubas, J. Research NBS* **63A,** *275 (1959).*

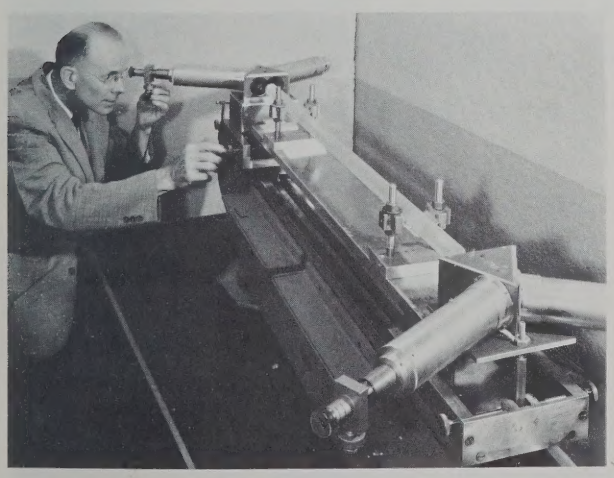
Resolved patterns of Zeeman splitting of thorium lines in a magnetic field of about 37,000 oersteds. From measurements of these patterns, constants are derived that are at present the best criteria for classification of spectral lines. The top spectrum is of light polarized perpendicular to the magnetic field; the bottom spectrum is of light polarized parallel to the magnetic field; the center spectrum is of light not under the influence of a magnetic field.



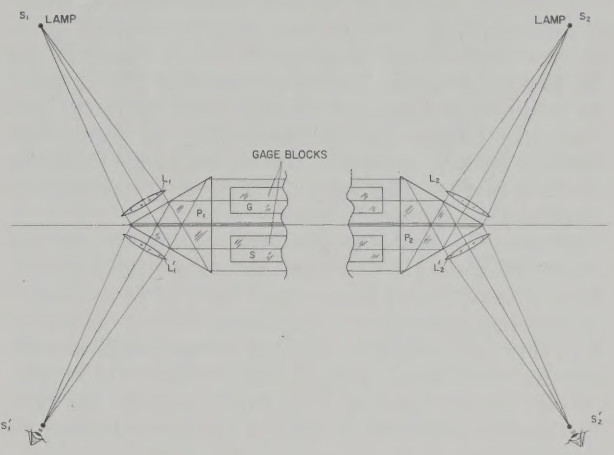
Gage Block Length Measurements with the parallel-testing interferometer

THE BUREAU has found that its parallel-testing interferometer,[1] developed a few years ago by J. B. Saunders for measuring the parallelism of the opposite faces of gage blocks, can be used without modification to compare the lengths of such blocks.[2] This method has the advantage of not requiring wringing which, when repeatedly applied, can injure the surfaces of gage blocks to the extent that reworking is often necessary. Furthermore, as blocks are measured in a horizontal position, use of the parallelism interferometer eliminates corrections for gravitational distortion in length measurements. Faster testing is another consequence of the technique, which makes it possible to measure blocks without handling, thus doing away with a major source of thermal disturbance.

As in other interferometers, the basic principle utilized in the parallelism testing instrument is that if two beams of light from the same source travel along different paths and then come together again, they will form a pattern of interference fringes, the order of interference depending on the difference in optical path length. This particular instrument actually consists of two interferometers, one for viewing each end of the block. In each interferometer, a Koesters double-image prism splits the light from a single source in such a way that a fringe pattern is formed by the interference of the rays reflected from the surface under study. If the two block surfaces are parallel, the fringe patterns in both eyepieces are also parallel; otherwise, the two sets of fringes



The Bureau has found that its special-purpose interferometer, used here by J. B. Saunders to measure the parallelism of the end faces of a glass rod, can also be used to campare the lengths of end standards.



Elements of the Bureau-designed parallelism interferometer as applied to length comparisons. Two gage blocks, *G* and *S*, are placed side by side in an interferometer consisting of Koesters prisms P_1 and P_2, lenses L_1, L'_1, L_2 and L'_2, sources S_1, and S_2, and eyepieces S'_1 and S'_2. A fringe pattern is obtained in each eyepiece and can be used to determine the difference in length of the two blocks.

are inclined by an amount that depends on the angle between the surfaces.

In applying this instrument to length comparisons, two gage blocks are placed side by side and each set of fringes is formed by the superposition of the images of neighboring ends of the blocks. The order of interference [3] at the center of each pattern thus formed is a measure of the relative position of the two end faces. The difference between the two orders of interference for any chosen wavelength is thus a measure of the difference in length of the blocks.

If the order of interference observed on one pair of faces is adjusted to zero, the difference in length is given by the order of interference observed on the second pair of faces. The length of the unknown block need not approximate the length of the standard. If the difference is large, however, the orders of interference will also be large and monochromatic light of high purity must be used to produce fringes of adequate visibility.

[1] Interferometer for measuring gage block parallelism, *NBS Tech. News Bull.* **42**, *30 (1958)*; The parallel testing interferometer, *by J. B. Saunders, J. Research NBS* **61**, *491 (1958) RP2917.*

[2] A new method of measuring gage blocks, *by J. B. Saunders, J. Research NBS* **64C**, *No. 3, 173 (July–Sept. 1960).*

[3] *A. Perot and Ch. Fabry,* Méthodes interférentielles pour la mesure des grandes epaisseurs et la comparison des longuers d'onde, *Ann. chim. phys.* **16**, *289 (1899).*

Intercomparison of

Laboratory Test Methods

A METHOD for evaluating mathematically factors involved in the variability of interlaboratory test results has been developed by J. Mandel and T. W. Lashof.[1,2] This "model" for statistical analysis has been successfully applied to several problems involving both physical and chemical properties of materials. A better appraisal of test methods can be made by utilizing the method to distinguish between random and systematic sources of error.

While the model is designed primarily for the study of a single test method on an interlaboratory scale, it can also be used for the interlaboratory comparison of two alternative test methods. For this purpose, it is applied in conjunction with another statistical procedure, the sensitivity criterion,[3] involving the functional relation between the results obtained by use of the two alternative test methods.[4]

The true reproducibility and therefore the usefulness of a method of measurement are unknown until the method has been evaluated on an interlaboratory scale. However, the interpretation of data from interlaboratory roundrobins is not always straightforward. There has been need for a clearly formulated model that would relate mathematically the various factors entering into the measurements. In recent years, considerable attention has been given to studies of test methods involving relatively large numbers of laboratories. These studies resulted from the observation that even when well-established methods of measurement are used, the agreement among laboratories is, in general, much less satisfactory than the agreement which can be achieved within a single laboratory.

The sources of variability usually considered in such studies include:

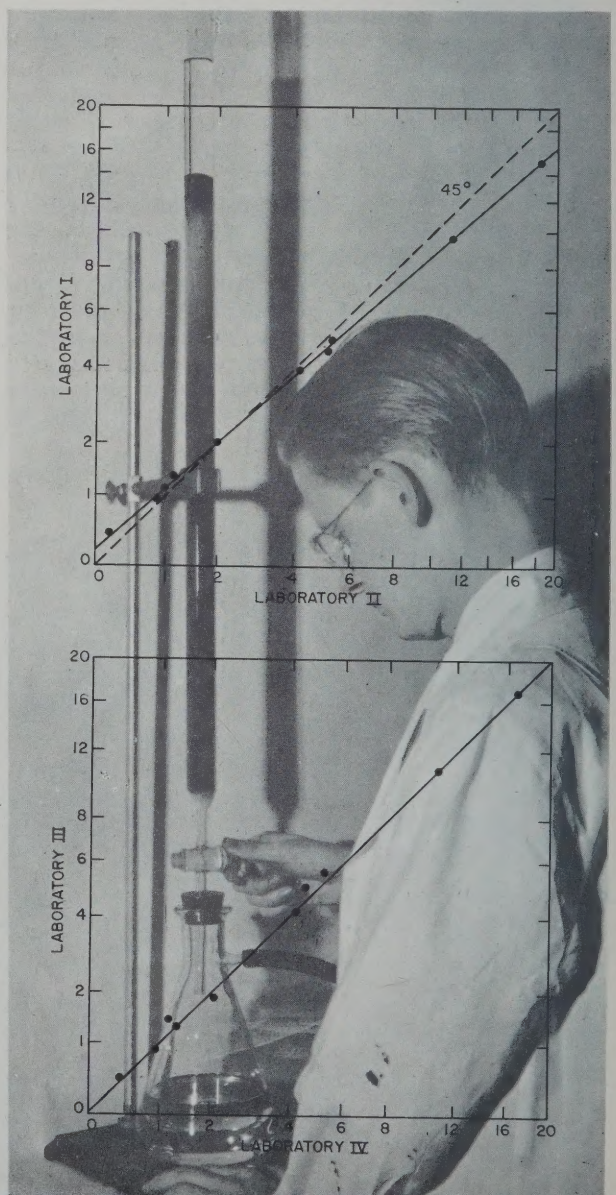
(1) Replication error, or differences among results obtained at one laboratory by one operator using the same instrument on specimens of the same material;

(2) laboratory main effect, or systematic constant differences among results obtained at different laboratories; and

(3) laboratory-material interaction, or variations among laboratories in the differences among results obtained for various materials.

The present method separates the third source of variability into two components; one is random and the other reflects systematic laboratory differences that cannot be represented by constant biases. To account for the random scatter one must consider, in addition to replication error, the effects, upon the measured value, of properties other than that property being measured. The interfering effect of such properties often varies among laboratories, causing additional scatter in the interlaboratory results. Another source of random scatter is improper calibration of equipment. In certain instruments having multiple scales, part of the random scatter has been shown to arise from lack of continuity among the scales or from variation in the ratios among the scales.

In the absence of systematic errors, a graph of the results from one laboratory plotted against those from another shows a scatter of data points about a straight line bisecting the angle formed by



Below: Results from two laboratories obtained on 10 samples. There is no appreciable systematic difference and the 45° line through the origin is for all practical purposes the line of best fit. Above: Results from two other laboratories obtained on the same 10 samples. There is a varying systematic difference; the line of best fit is not at 45° to the axes nor does it pass through the origin.

the axes (a line of 45° slope). If the results from one laboratory were consistently higher or lower by a constant amount than those from the other, the line would be higher or lower but would be parallel to the first line; that is, it would lie at 45° to either axis but would not pass through the origin.

In practice, the lines obtained are not of 45° slope, and it is this nonparallelism or slope effect that reflects a varying systematic difference between the two laboratories. For example, an error in the determination of the normality of a reagent will cause a proportional type of error in all analyses employing this reagent. For any number of laboratories, the slope effect can be generalized by plotting the results from each laboratory against the average of the results from all.

The separation of various error sources provided by this method permits evaluation of possible benefits derivable from reference samples. In the case of constant differences among laboratories, a single reference sample is sufficient. If the slopes of the lines plotted for various laboratories differ to a great extent, the use of two reference samples is indicated. Suppose that specimens of two reference materials are supplied to all participating laboratories. The two materials, although necessarily similar in nature, must differ considerably in the value of the property under test. The values for this property obtained by measurement in any given laboratory for these two materials can be compared with the known correct (or assigned) values; then at each laboratory the measured values for any submitted unknown sample of such material can be "adjusted" and brought into line with the similarly adjusted values from other laboratories.

The use of reference samples to improve interlaboratory precision is an accepted procedure and differs little from some calibration methods; however, reference samples should be used for this purpose only after all economically feasible improvements in the control of environmental conditions or other desirable modifications of the test procedure have been exhausted.

Most statistical methods are highly sensitive to extremely discrepant values. The present method contains several safeguards against misleading results due to the inclusion of outlying measurements. Standard deviation of replication error is examined for each material and laboratory. Single discrepant values are then easily detected from inflation of the corresponding standard deviations. Trends are handled statistically through appropriate transformations of scale. If all the replicates obtained by one laboratory for a particular material are affected by the same error, the contribution of this laboratory to the random part of the laboratory-material interaction will be unduly large and consequently obvious. A laboratory discrepant in all values will be apparent from the fact that its line will differ from the others appreciably in position or slope.

Sometimes these discrepancies can be clarified and the nonconforming values replaced by the results of measurements taken under proper conditions. When no reason for the conflict can be found, the values must be considered as possibilities in the application of the test method.

[1] The measuring process, *by John Mandel, Technometrics, 251 (1959).*

[2] The interlaboratory evaluation of testing methods, *by John Mandel and T. W. Lashof, ASTM Bul.* **239,** *53 (1959).*

[3] *The sensitivity of a method A used in the study of a property Q is defined as* $(\triangle A/\triangle Q)/\sigma_A$, *where A is the measurement obtained and* σ_A *is the standard deviation of method A.*

[4] Evaluation of test methods by the sensitivity criterion, *NBS Tech. News Bul.* **40,** *139 (1956).*

Megaroentgen Dosimetry Method Using Commercial Film Without Processing

X-AND GAMMA-RAY exposure doses in the megaroentgen range can now be measured by means of a simple film method developed at the Bureau with the support of the Atomic Energy Commission. This method,[1] devised by W. L. McLaughlin of the Bureau's radiation physics laboratory, extends the exposure range of commercial photographic film to 10^8 roentgens (r) by employing a special densitometric procedure. No photographic processing of the film is required.

Dosimetry in the megaroentgen range is important to the study of radiation-induced changes in materials, the field of radiobiology, and the irradiation of foodstuffs for long-term preservation. Various chemical, glass, and solid-state dosimetry methods are presently in use; however, no one method has yet been selected as the most satisfactory for routine field use. Indications are that the Bureau's method will provide a useful means of measurement in this range.

For many years, photographic film has been used for X- and gamma-radiation dosimetry in the range from 10^{-2} to 10^4 r. The exposure of undeveloped photographic film to X- or gamma rays in this range results in the formation of microscopic aggregates of silver atoms in the minute silver halide crystals of the film. These aggregates are the smallest units of the latent image. The small latent-image centers are increased in size by reducing agents, such as photographic developers, until the crystals containing the centers are replaced by irregular structures of free silver, which appear macroscopically as the photographic image. Radiation exposure values are obtained by measuring the resulting

A narrow-band pass filter passing only near-infrared radiation is placed between the exposed film and the light source when the change in film density due to print-out effect is read on a photoelectric densitometer.

increase in optical transmission density of the film with a photoelectric densitometer.

When the same film type is exposed to radiation levels above 10^4 r, the latent-image centers are enlarged to massive aggregates of silver. This process is known as print-out effect, and is essentially an extension of the process of latent-image formation. The individual silver halide crystallites become quite dark, forming the print-out image without photographic development.

Photographic dosimetry in the exposure regions above about 10^4 r has not been successful using the conventional methods because of the tendency of the developable latent-image formation to reach saturation or because of certain characteristic instabilities of the latent image. H. F. Nitka of Ansco has used the print-out process over the exposure range from 5×10^4 to 5×10^6 r; [2] however, his specially sensitized print-out paper showed a pronounced rate dependence. The method developed at the Bureau avoids these difficulties by employing the formation of the print-out image in various commercial X-ray film types.

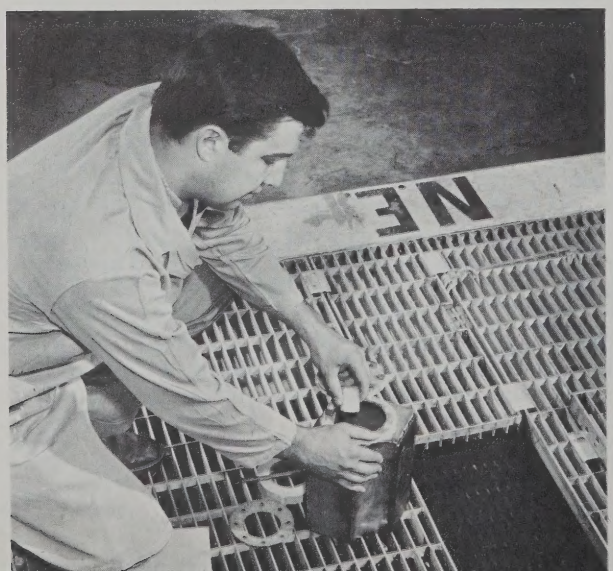
The Bureau found that exposures over the relatively wide range of 10^4 to 10^8 r can be measured with good reproducibility if a special densitometric procedure is used. The light source of a conventional photoelectric densitometer is filtered to pass only the narrow band of wavelengths—in the red or near-infrared—for which the decrease in transmittance of the film is a maximum. The net optical transmission film density is then related to the unknown radiation exposure through the use of experimentally determined calibration curves. Thus film types previously limited to the range from 10^{-2} to 10^4 r in photographic dosimetry can now be used for exposures up to 10^8 r.

The films investigated are insensitive to the spectral band in which the net optical density is a maximum. As a consequence, provided the densitometry is performed in a room illuminated only by red light, the films may be densitometered as often as desired without disturbing the print-out image. Also, since the formation of the print-out image results in a gross color change of the film samples, the method should lend itself to a rough visual reading procedure with the aid of a suitably calibrated color comparator, at least for exposures of about 10^6 r and above.

The most sensitive net density readings on an exposed film can be obtained by cutting the film into several pieces and then superimposing them during the densitometry. Readings using this technique were made on the most sensitive film type with 5-percent precision down to 10^4 r. The upper limit for the exposure that can be determined is defined by either the onset of film deterioration due to radiation damage or the tendency of the print-out image to reach a saturation density level. No readings can be made beyond 10^8 r.

Exposed films stored in their original packages at room temperature for six months showed no change in transmission density. For use in dosimetry the film packets should be enclosed in watertight envelopes to protect them from extraneous moisture and variations in atmospheric conditions.

Exposures of a number of film types were made at various radiation intensities between 2×10^2 and 5×10^5 r/hr, and no rate dependence was observed. Results from exposures made at different photon energies indicate that the energy dependence of the print-out process is similar to that of the conventional low-exposure-range photographic dosimeter, although it tends to be somewhat more pronounced with some film types. Because of a large energy dependence of the film response at photon energies below 0.3 Mev, an individual calibration would be necessary for each low-energy exposure condition, or suitable metallic filters should be used to equalize the film response.



W. L. McLaughlin places an unexposed film sample sandwiched between two plastic pieces into a watertight container to be lowered into the pool of water surrounding the Bureau's 2,000-curie multirod system of Co^{60} sources.

The print-out response becomes more sensitive as the ambient temperature increases during the exposure, but it was found to vary by not more than 10 percent for exposures at ambient temperatures in the range from 10 to 40 °C. Over the range from −10 to +60 °C, variations in response as great as 50 percent were encountered.

Despite the energy and temperature dependence of the method, it appears to satisfy most of the requirements of a working technique for megaroentgen dosimetry. The method is presently being studied under field conditions.

[1] *For further information, see* Megaroentgen dosimetry employing photographic film without processing, *by William L. McLaughlin, Radiation Research* **13** (to be published).

[2] Photographic methods in measuring large radiation doses, *by H. F. Nitka, Nucleonics* **17**, *58 (1959)*.

FADING-RATE RECORDER

TO AID in radio wave propagation studies, the Bureau has devised an instrument, under the sponsorship of the U.S. Air Force, to record the rate at which received signals fade. Developed by B. B. Balsley and improved by W. B. Harding, R. J. Jansen, and J. W. Koch, all of the Bureau's Central Radio Propagation Laboratory at Boulder, Colo., the instrument records the number of times per second that a signal envelope crosses the average signal level with a positive slope. It records fading rates down to almost 0 c/s and as high as 300 c/s.

Such irregularities in the atmosphere and ionosphere as humidity, temperature, pressure, and index of refraction can combine to cause more than one propagation path to exist between transmitter and receiver. Each path, traveling over a different route, will have a different length. If all the signals arrive in phase, the received signal will be strengthened; if they arrive out of phase, there may be cancellation and the signals will fade. This phenomenon is called multipath fading. Comparison of fading rate records with signal intensity records obtained simultaneously provides a useful aid in interpreting simple mode propagation.

Although the instrument records the rate of average rather than median signal crossing, and hence may not strictly agree with fading rates as frequently defined, it does provide a convenient means for comparing average fading rates for various propagation conditions and transmission frequencies. The results of the fading-rate records must be applied cautiously to communications problems, as the depth of fading and amplitude distribution of the envelope vary considerably. The device gives no indication of these factors.

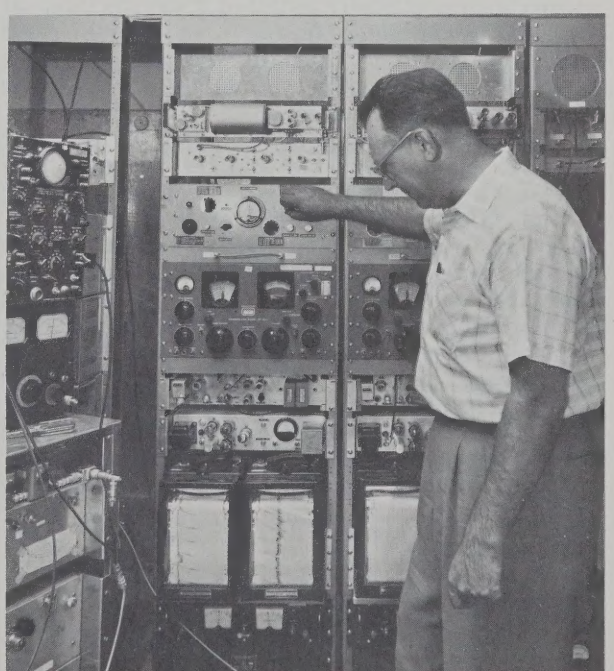
The recorder operates from the intermediate frequency output of a receiver that has a 12-sec or longer AGC time constant. The signal from the IF is applied to an integrating circuit with a 6-sec time constant to determine the average signal level. The continuously varying signal is compared to the average signal, and when it rises above the average level it turns on a Schmitt trigger circuit. When the signal drops below the average level, the trigger turns off. The square-wave output of the Schmitt trigger is differentiated, and the resulting positive pulse indicates when the signal crosses the average level in a positive direction.

This pulse output is integrated, amplified, and then applied to a strip-chart recorder. The voltage to the recorder is proportional to the number of one-shot pulses each second from the Schmitt trigger circuit; hence the recorder indication is a linear function of fading rate.

The fading-rate recorder has proved to be quite stable in operation after the initial warmup period, when used with regulated power supplies. Even though d-c coupling is used between all stages up to and including the Schmitt trigger, the circuitry is designed so that negligible drift occurs in the critical operating voltages.

Flutter fading at rates up to 20 c/s has been noted in typical recordings for radio paths through the auroral zone. Other recordings show a change in fading rate when the signal level suddenly changes; probably the propagation mode has changed at these times. Spikes on fade records have occurred even when the transmitter is off; these spikes are probably caused by noise fluctuations. Occasional noise spikes are noted on the Bureau's radio station WWV recordings. These spikes appear to result from impulse noise interference.

Harry C. Petrie of the Bureau's Central Radio Propagation Laboratory operates the fading-rate recorder developed and constructed there.



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Microvolt Calibration Console

A MICROVOLT calibration console developed by the Bureau for its Electronic Calibration Center at Boulder, Colo., provides a rapid, accurate means for calibrating signal generators that have low-level RF outputs. Designed by L. F. Behrent, F. X. Ries, and M. C. Selby, the console covers a range from 1 to 100,000 μv at 10 frequencies from 30 kc to 400 Mc. Overall accuracy of measurement is 2 to 5 percent depending on the frequency. The microvolt calibration console provides the Bureau with an additional calibration facility to help meet the continually expanding needs of Government and industry for electronic standards and calibration services.

A signal generator can be calibrated on this console in about one-half the time previously required using RF micropotentiometers, and in about one-fifth the time needed by more cumbersome methods. The improvement in efficiency is a result of grouping in a single installation all of the components necessary for calibrating a signal generator, with simple controls to connect the appropriate frequency sources and reference standards to the equipment under test. For convenience, RF power is furnished from RF voltmeter calibration consoles [1-4] located in another part of the Electronic Calibration Center. The system could, however, be made completely self-contained by adding RF sources to the console itself. The reference standards used are carefully calibrated RF micropotentiometers.

Each RF source is crystal controlled, has harmonics suppressed 60 db or more, and voltage output stability of 0.1 percent over a period of 15 to 20 min. By remote control, the operator at the microvolt console can turn on any one of the RF sources that is not in use for other calibrations. At the same time, the RF power output from the source is automatically switched from the internal load of the voltmeter console to an external rigid coaxial line which transmits the energy to the microvolt console. A servo-motor control adjusts the level of the RF power.

To calibrate a signal generator, an RF source of the appropriate frequency and the corresponding receiver are selected with a frequency selector switch. Before RF power is applied to the console, a reference standard with an output voltage required for a given calibration range is connected to the RF source circuit. The servo-motor control is then adjusted to bring the RF voltage output of the reference standard approximately to the desired working level. With the generator under calibration tuned to the same frequency as the RF source, and with its output adjusted to the level to be calibrated, the receiver is connected alternately to the signal generator and to the secondary standard, and the output of the latter is then adjusted until the receiver indicates that both RF levels are equal. The d-c millivolt output indication of the reference standard is noted, the RF power is removed and, for best accuracy, the thermocouple of the reference standard is calibrated with a built-in d-c source. The actual RF voltage output of the micropotentiometer, and hence of the signal generator, can then be calculated since the d-c resistance and the d-c-to-RF characteristics of the RF micropotentiometer resistance elements are known.

To obtain a wide range of voltage values, 12 RF micropotentiometers with overlapping ranges are used as secondary standards. With this number of units, each standard can be intercompared with those covering adjacent voltage ranges. A coaxial switch on the front of the console connects the RF power to any one of the standards and simultaneously connects the indicating d-c millivoltmeter to the thermocouple output of the RF micropotentiometer in use. An impedance in series with each RF micropotentiometer improves the impedance match to the RF source and prevents overload damage by limiting the RF power supplied to the standard.

For frequencies of 30 Mc and below, independent crystal-controlled receivers are used as detectors for comparing the magnitude of the "unknown" voltage against the standardized voltage of the RF micropotentiometer. At the higher frequencies, converters with crystal-controlled oscillators are used with a single 30-Mc receiver.

The frequency selector switch, which selects the proper RF source, also connects the appropriate receiver to a differential voltmeter. A step attenuator is permanently connected to the receiver imput to reduce large signals to a working level that does not saturate the receiver. Matching networks or additional external pads may be connected to the imput of the flexible coaxial cable of the receiver, to insure that the impedance loading the signal generator under calibration is accurately known. A stable, accurately measured source of direct current is also incorporated in the console for calibrating the thermocouples of secondary standards or of RF micropotentiometers submitted for test.

To calibrate an "unknown" RF micropotentiometer, it is connected to a second section of the console provided for this purpose. RF power, supplied from the same source as above, is gradually increased to a desired level of the "unknown." The RF level of the standard is then adjusted until the receiver indicates equal output from each. With the RF power disconnected, the thermocouples in both the "unknown" and the

standard are calibrated with the internal d-c source; the RF voltage is then calculated.

[1] *M. C. Selby, L. F. Behrent, and F. X. Ries,* Rf voltmeter calibrating consoles, *IRE National Convention Record,* **5,** *251 (1958).*

[2] *M. C. Selby,* Accurate rf microvoltages, *AIEE Communication and Electronics* **6,** *158 (1953).*

[3] *L. F. Behrent,* Fabrication of radio-frequency micropotentiometer resistance elements, *J. Research NBS* **51,** *1 (1953) RP2426.*

[4] *M. C. Selby,* Rf micropotentiometers, *Radio & Television News, Engineering Edition* (1953).

Optical Properties of Condensed Gases

A METHOD to determine the optical properties of thin films of gases condensed on metal surfaces at low temperatures[1] has resulted from Bureau research on free radicals for the Department of the Army.[2] In the procedure, devised by Jerome Kruger and William Ambs of the metallurgy laboratories, the refractive index of a substance is found by comparing data derived experimentally with data processed by an automatic computer. Results of the study are being used to determine the optical properties of thin films of other substances.

In the ellipsometer employed to study reactions on metal surfaces, a beam of polarized light is reflected from the surface in such a way that the ellipticity and orientation of the beam are altered after reflection. These properties are related both to the thickness of any film on the surface and to the film's refractive index. However, the relationship is expressed in the polar form of complex numbers and is so complicated that the refractive index of the film cannot be readily calculated.

A technique was therefore devised in which readings are taken with the ellipsometer at several unknown thicknesses, and from these data a curve is plotted of the change in ellipticity versus the change in orientation after reflection. Various values of refractive index and film thickness are then assumed, and the corresponding instrument readings are computed by the Bureau's high-speed electronic computer. From the resulting data automatically processed, several curves are plotted and compared with the experimental curve previously derived. The correct refractive index for a particular film is found when a theoretical curve matches the experimental curve.

The gases investigated in the present study were argon, carbon dioxide, krypton, neon, nitrogen, oxygen, and water. To conduct the experiments, a metal mirror was mounted on a holder in a removable liquid-helium "cold finger" that had been fitted into a Dewar flask. The gas was admitted through a capillary in the Dewar and was condensed on the cooled mirror at temperatures as low as 4.2 °K. The ellipsometer, focused on the metal specimen, was adjusted to achieve minimum light intensity so that readings of ellipticity and orientation could be made as the thickness of the film changed.

In some of the experiments the gas was passed through a microwave discharge just before entering the Dewar. This discharge had the effect of dissociating the molecules of oxygen, nitrogen, carbon dioxide, and water, and of raising the atoms of the other gases to an excited state. Small percentages of the free or excited atoms were then trapped on the cold mirror, where they had lifetimes sufficiently long to be observed.

Refractive indices found for the condensed gases are given in the table. The values listed are precise to within ±0.01. The table shows that passage of a gas through the microwave discharge affects the refractive index of the film formed from the discharge products, except in the case of nitrogen and krypton.

Experimental apparatus used in determining the refractive indices of thin films of gases condensed on metal surfaces at low temperatures. William Ambs checks the liquid helium level in the Dewar assembly, which contains a metal specimen.

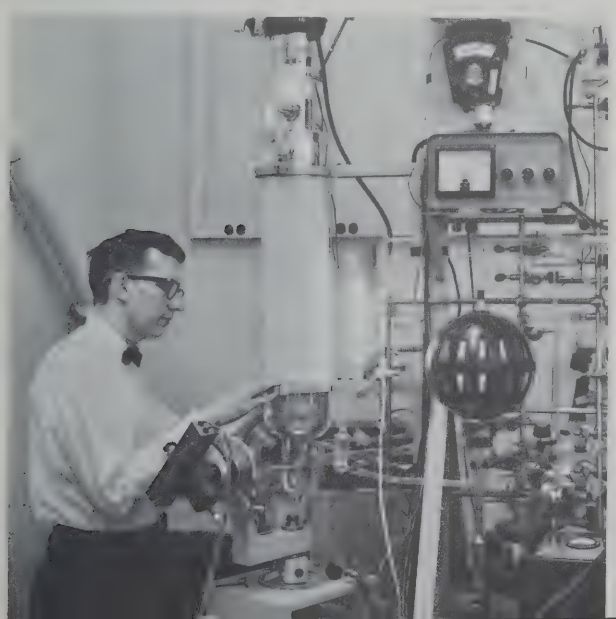


Table of refractive indices of thin films of gases condensed on a gold mirror. Wavelength 5461 A.

Gas	Treatment	Temperature of disposition	η
		°K	
Argon	undischarged	4.2	1.26
	discharged	4.2	1.27
Carbon dioxide	undischarged	77	1.34
	discharged	4.2	1.26
Krypton	undischarged	4.2	1.22
	undischarged	4.2	1.28
	discharged	4.2	1.28
Neon	undischarged	4.2	1.23
	discharged	4.2	1.24
Nitrogen	undischarged	4.2	1.22
	discharged	4.2	1.22
Oxygen	undischarged	4.2	1.25
	discharged	4.2	1.28
Water	undischarged	4.2	1.19
	discharged	4.2	1.30
	undischarged	77	1.20
	discharged	77	1.25

The difference found in the refractive index of some of the gases in the undischarged and discharged conditions may be attributed to the formation of new molecular species in the gas stream prior to condensation rather than to the trapping out of free radicals. Thus, O_2 may form O_3; CO_2 may form CO and O_2; H_2O may form H_2O_2. The different refractive indices determined for water and carbon dioxide at the two condensation temperatures employed are probably the result of changes in degree of crystallinity.

[1] *For further technical details, see* Optical measurements on thin films of condensed gases at low temperatures, *by J. Kruger and W. J. Ambs, J. Opt. Soc. Am.* **49**, *1195 (1959).*

[2] *For a summary of the Bureau's research on free radicals, see NBS Tech. News Bul.* **44**, *100 (1960).*

Determination of Minute Concentrations of Aldehyde in the Atmosphere

THE BUREAU, in a program sponsored by the Public Health Service, has developed a rapid, simple method [1] for determining minute amounts of aldehyde in air. With this colorimetric technique, it is possible to detect amounts of aldehyde as low as 0.1 part per billion (ppb) and to distinguish between concentrations differing by a half order of magnitude. Particularly effective in studying air pollution, the method is easily adapted for field use.

Besides its uses in monitoring air pollution, the procedure can be applied to other industrial or laboratory processes requiring the detection of minute quantities of aldehydes in noncondensible gases.

In the analytical procedure, devised by E. E. Hughes and S. G. Lias of the gas analysis laboratory, the dispersed aldehydes are concentrated by adsorption on pure silica gel. The gel surface is then treated with a solution of *p*-phenylenediamine and hydrogen peroxide. The color resulting from this reaction is indicative of the quantity of aldehyde present. By visually comparing this color with reference samples, the aldehyde concentration is determined.

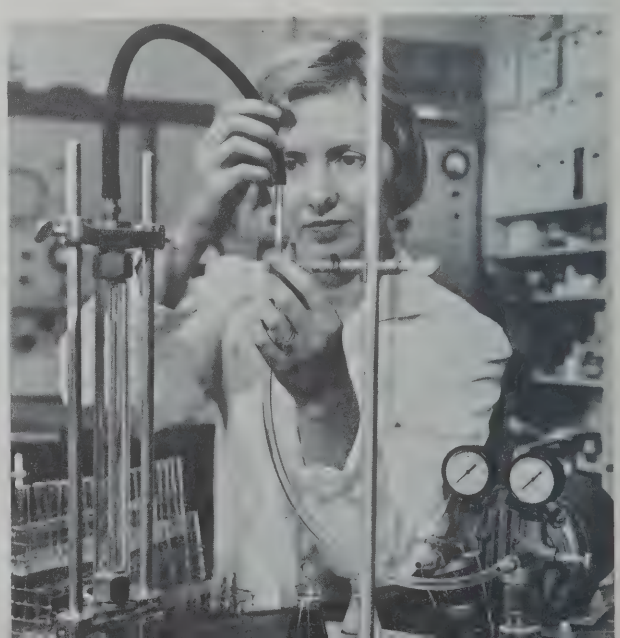
The normal concentration of aldehyde found in urban atmospheres is produced by industrial processes and the operation of motor vehicles. Hundreds of tons of exhaust products containing small quantities of aldehydes are poured into the atmosphere daily from internal combustion engines. Under normal conditions these exhaust products are dispersed in the atmosphere at very low concentrations. In certain urban areas, weather conditions may prevent normal dispersal of these contaminants. Strong sunlight then initiates a photolytic reaction which converts the exhaust products to an irritating mixture commonly referred to as "smog." Because aldehydes are prominent in the oxygenated compounds resulting from this photolysis, analysis of their concentration provides a useful index of the amount of ordinary exhaust fumes converted to smog.

In designing a test for rapidly determining minute quantities of substances in gases, two major obstacles must be considered. First, these substances are usually too widely dispersed to measure directly. Aldehydes, for example, usually occur at concentrations between 1 ppb and 1 ppm per volume of air. Thus, a collecting medium must be used which will concentrate the substance from a large volume of air into a small volume. Silica gel has been used as a collecting medium for air contaminants [2] and has proved quite satisfactory. Through small tubes containing silica gel, large volumes of air can be sampled at flow rates which yield significant quantities of aldehyde in short periods of time.

Second, a reaction must be available in which the product is not only highly visible in the collecting medium but is also proportional to the quantity of concentrated sample. In the colorimetric reaction used by the Bureau, aldehydes catalyze the oxidation of the phenylamines by hydrogen peroxide. At any time during this reaction, the concentration of the product—a dark quinoidal compound—is always proportional to the aldehyde concentration but greatly exceeds it.

To begin an analysis by the Bureau method, silica gel is poured into glass tubes each having a wad of cotton inserted in one end. After the required quantity of air is drawn through the gel with a syringe or pump, an additional amount of gell is added to the exposed end of the tube. The tube is then closed with a second cotton plug. The gel added after exposure serves as a filter

Measuring minute quantities of aldehyde in air by a colorimetric technique developed by the Bureau. S. G. Lias sets up the compact portable equipment which can easily be adapted to field studies.



to remove the dark oxidation products which are always present in the developing reagent.

Next, the tube is dipped into the fresh reagent solution—*p*-phenylenediamine and hydrogen peroxide—which rises through the gel by capillary action. If aldehyde is present in the sample of air, a dark ring appears at the junction of the two gel layers. The color of this ring ranges from light purple to black, depending on the aldehyde concentration.

Because the reaction proceeds at a finite rate in the absence of aldehydes, each test must be compared with reference standards after the same time interval.

The comparisons are made with tubes prepared with silica gel dyed to approximate the appearance of actual exposed tubes. Accurate reference samples are obtained by calibrating the mock specimens against tubes containing known aldehyde concentrations.

[1] Detection and estimation of low concentrations of aldehyde in air, *E. E. Hughes and S. G. Lias, Anal. Chem.* **32**, 707 (*1960*).

[2] *A companion method for detecting acetylene in low concentrations was recently developed. See* Determination of acetylene in low concentrations for air-pollution control, *NBS Tech. News Bul.* **42**, *203* (*1958*).

High-Temperature Nickel-Aluminum Coatings

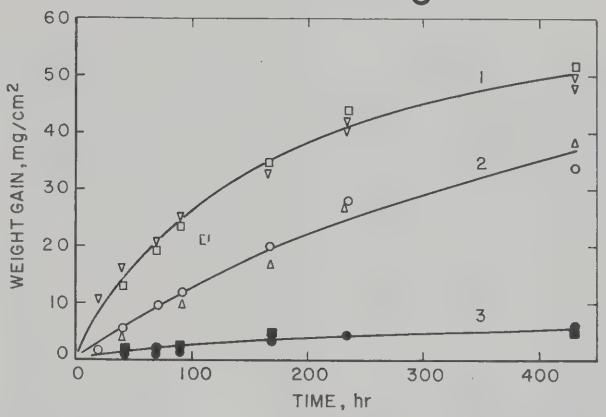
THE BUREAU, in a program sponsored by the Wright Air Development Center, has developed a method[1] for producing nickel-aluminum alloy coatings capable of protecting metals from oxidation at temperatures up to 1,000 °C. The coatings can be used to advantage on many types of aeronautical equipment. The most durable coating was obtained by electroplating nickel over the basis metal and then plating aluminum on the nickel at 700° C.

Although cast nickel-aluminum alloys have good corrosion-resistance to atmospheric exposure and maintain their hardness at elevated temperatures, their brittleness prevents them from being fabricated into intricately shaped components. However, by utilizing the alloy as a coating—rather than as a basis metal—and electroplating it on more ductile metals, an effective corrosion-resistant material can be obtained.

In an attempt to find suitable plating conditions for producing a smooth, oxidation-resistant nickel-aluminum coating, D. E. Couch and J. H. Connor of the electrodeposition laboratory studied aluminum plating baths prepared from either organic solvents or fused salts.

The most satisfactory procedure consisted in electrodepositing nickel from a Watts type of bath, i.e., a mixed chloride-sulfate bath, and then electroplating aluminum on the nickel layer at a current density of 2 to 15 amp/dm^2. The aluminum was deposited from a fused salt solution containing a mixture of potassium chloride, sodium chloride, and cryolite (sodium aluminum fluoride) at 700 °C. At this temperature, aluminum diffuses into the nickel layer, as it deposits, thus forming the alloy.

Nickel-aluminum alloy produced in the sodium chloride-potassium chloride-cryolite bath at 700 °C. The most durable coating was obtained by this process. This deposit was heated 2 hr at 1,000 °C after plating. (×211)



Comparing oxidation of nickel and nickel-aluminum alloy coatings at 1,000 °C. By using the Bureau's technique for coating metals with a nickel-aluminum alloy, metals can be protected from oxidation at temperatures up to 1,000 °C. Curve 1: □, ▽, pure nickel, duplicate sample. 2: ○, △, alloy coating, about 8μ, duplicate sample. 3: •, ■, alloy coating about 25μ, duplicate sample.

In the cryolite deposition, samples plated with nickel were placed in the bath in a graphite container and allowed to heat up to bath temperature before electrolysis. Excellent adhesion was obtained on nickel, and on previously prepared nickel-aluminum alloys. At 700 °C, an aluminum deposit 6–μ (0.00025-in.) thick was produced by using a current density of 7 amp/dm^2 for 5 min. However, when the electrolysis was continued under these conditions for a longer period of time, the aluminum was electrodeposited faster than it could diffuse into the nickel. The excess aluminum dripped off the bottom of the sample. Thicker deposits could be produced by using a lower current density for a longer time, or by operating at a higher temperature.

For objects which require coatings, but which cannot withstand the high temperature necessary to operate the cryolite bath, an alternate method for plating aluminum is used. In this procedure, aluminum is deposited over the nickel at 160 °C from a fused salt bath consisting of aluminum chloride and sodium chloride and then alloyed

with the nickel by heating for a few hours at 500 to 600 °C in air.

Steel specimens coated with the aluminum-nickel alloy were tested in the salt-spray, in outdoor exposure, and in air at elevated temperatures. In air at 550 and 1,000 °C, the alloy coatings oxidized at one-tenth the rate of nickel coatings of comparable thickness. In the salt-spray tests, the panels plated from the cryolite bath proved to be the most durable. In fact, steel panels coated with 0.002 in. of nickel and 0.0005 in. of aluminum withstood 300 hr in salt-spray tests before showing rust. Also, rapid thermal cycling of these panels between room temperature and 550 °C did not affect their corrosion resistance. The coatings were more resistant when the aluminum thickness was less than 50 percent of the total coating thickness. Corrosion studies conducted on atmospheric exposure racks correlated well with the salt-spray tests. The alloy-coated panels did not show rust at the end of one year; in comparison, nickel-plated controls rusted after four months.

The coatings provide suitable protection for steel, nickel, and molybdenum,[2] and are probably applicable to other metals. Coatings 50 μ (0.002 in.) thick protected steel from oxidation at 550 °C, but did not afford adequate protection at 1,000 °C because the iron diffused through the coating. Thicker coatings would probably be satisfactory.

[1] *For further technical information see,* Nickel-aluminum alloy coatings produced by electrodeposition and diffusion, *D. E. Couch and J. H. Connor, J. Electrochem. Soc.* **107,** *272 (1960).*

[2] *J. Electrochem. Soc.* **105,** *450 (1958).*

FATIGUE PROPERTIES OF SOME HIGH-STRENGTH STEELS

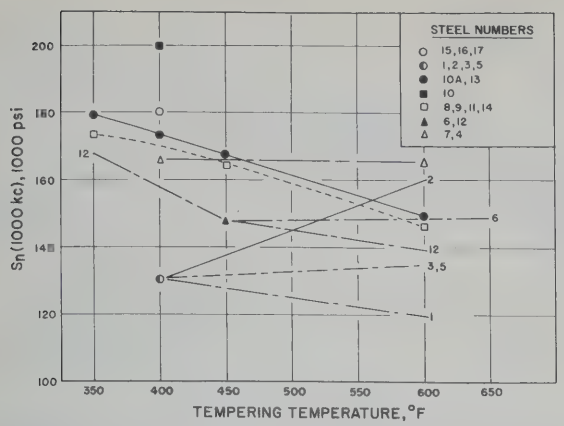
Fatigue cracks in high strength steels sometime originated below the surface of a specimen and propagated toward the surface. The fracture surface of one of the specimens in which this occurred is shown here. (×435)

STEELS heat-treated to high tensile strengths that contained copper as an alloying element demonstrated better fatigue properties than similar steels without copper, in a recent Bureau study for the Army's Frankford Arsenal. The amount of copper in the alloy appears to be crit-

Chemical composition, percent by weight

Steel	Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Copper
1	0.40	0.71	0.33	0.81	1.67	0.25	0.15	----------
2	.31	.91	.31	.89	1.86	.41	.07	----------
3	.33	.91	1.63	.81	1.66	.42	.07	----------
4	.25	1.38	1.48	.05	1.80	.42	----------	----------
5	.27	1.41	1.50	.34	1.78	.44	----------	----------
6	.43	.82	1.51	.73	0.84	.48	.07	----------
7	.42	.85	1.49	1.00	2.01	.50	.11	----------
8	.45	1.35	0.15	0.77	0.03	.68	.21	0.09
9	.45	1.33	.38	.80	.02	.69	.21	.74
10	.45	1.40	.17	.83	.06	.68	.17	1.28
10A	.48	1.18	.19	.82	.05	.66	.17	1.32
11	.46	1.42	.23	.86	.03	.68	.22	2.13
12	.45	.53	.14	.78	.04	.66	.21	0.74
13	.46	.52	.20	.79	.05	.66	.21	1.28
14	.49	.52	.16	.78	.05	.65	.20	2.06
15	.31	1.54	.21	.83	.06	.67	.19	1.29
16	.32	1.49	.20	.84	.06	1.04	.18	1.28
17	.26	1.22	.12	.85	.06	0.68	.18	1.28

NOTE.—Prior history of the steels:
1. A vanadium-modified AISI 4340, taken from a gun chamber made by upsetting seamless tubing.
2. A vanadium-modified steel of AISI type 4330, product of a 2,000-lb induction heat rolled to 1-in. round.
3. Experimental 500-lb induction heat press forged to 6-in. square from 13-in. ingot. Hammer forged to ½-in. square.
4. Vacuum melted.
5. Received as an 8-in. round and forged to 1-in. square for specimens.
6. Product of a 7-ton electric-furnace heat forged to 1½-in. square for specimens.
7. 100-lb induction heats, rolled to 1-in. diam rounds for specimens.
8–17. Experimental steels, 100-lb induction heats, rolled to 1-in. diam rounds for specimens.



Fatigue strengths at 10^5 cycles of 18 high-strength steels, as influenced by tempering temperature.

ical, with 1.3 percent by weight giving optimum strength when low-tempering temperatures have been employed. These results, obtained in a study of both commercial and experimental steels, may have practical applications in the future production of fatigue-resistant materials.[1]

The steels developed in the past several years having tensile strengths above 200,000 psi have created widespread interest because of their many potential applications. However, few data are available on the fatigue characteristics of these steels, even though their behavior under conditions inducing fatigue—fluctuating or repeated stresses—is sometimes important. Hence, to provide the required data, H. E. Frankel and J. A. Bennett of the Bureau staff and C. M. Carman of the Frankford Arsenal, undertook the present study.

Over 350 specimens of 18 different steels were investigated. Their chemical compositions and premachining histories are given in the table. After heat treatment, the specimens were tempered for 4 hr in a circulating air furnace at temperatures from 350 to 600° F, and then carefully polished and coated with a rust-preventive oil. Rotating-beam fatigue tests were conducted on R. R. Moore-type machines operated at speeds of from 1,000 to 2,000 rpm.

In analyzing the test results, comparisons were made on the basis of a common condition, such as tempering temperature, as well as on the basis of similar composition, with perhaps one element varied. Because of the similarity in the results for certain groups of steels, similar data were combined and a determination made of the best value of fatigue strength at 10^5 cps for each group. No attempt was made to determine the fatigue limits of the different steels.

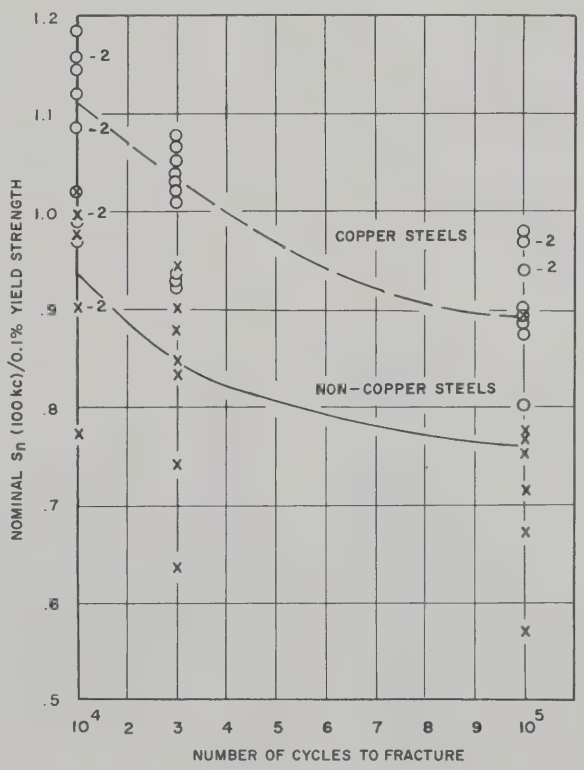
Fatigue-strength/yield-strength ratios at three points on each *S–N* curve. The number 2 adjacent to a point indicates that the point represents two steels. The higher strength of the copper steels may be due to the precipitation of copper under the influence of fluctuating stress.

Six of the experimental steels contained approximately 1.3 percent copper. These steels, when tempered at 350 or 400 °F, had higher maximum fatigue strengths as well as greater fatigue-strength/yield-strength ratios than any of the others. It is suggested that the generally superior fatigue properties of the materials containing copper may be due to the precipitation of copper under the influence of the fluctuating stress. Some of the copper-bearing steels showed a marked tendency for subsurface initiation of fatigue cracks. Of the 32 specimens of the 4 steels that had the best fatigue properties, 21 specimens had cracks originating below the surface. Specimens of all the other materials developed normal fractures with the crack nucleus on the surface.

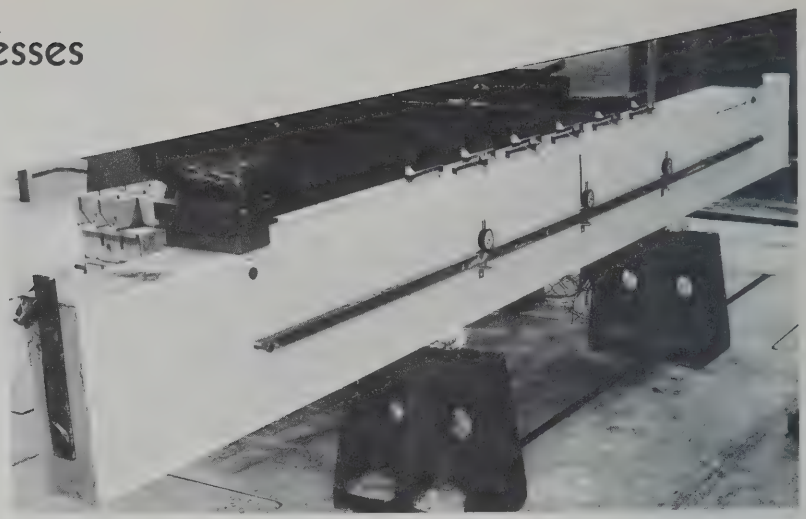
A previous study had shown that increasing carbon content in steel alloys required higher hardnesses to attain equivalent fatigue strengths.[2] Although the specimen preparation in the present study was different from that in the earlier work, the same general tendency was noted. It was found that in steels of similar composition there is a decrease in the fatigue-strength/yield-strength ratio with increasing carbon content.

[1] *For further technical details see* Fatigue properties of some high-strength steels, *by H. E. Frankel, J. A. Bennett, and C. M. Carman, ASTM 1960 Preprint No. 65.*

[2] Fatigue properties of high-strength steels, *by H. E. Frankel, J. A. Bennett, and W. A. Pennington, Trans. ASM* **52** *(1960)* ; *and NBS Tech. News Bull.* **43,** *74 (1959).*



Effect of High Stresses on Reinforced Concrete Beams



Thirteen-foot concrete beam about to be tested for effect of magnitude of steel stresses on flexural behavior in a 600,000-lb-capacity hydraulic machine.

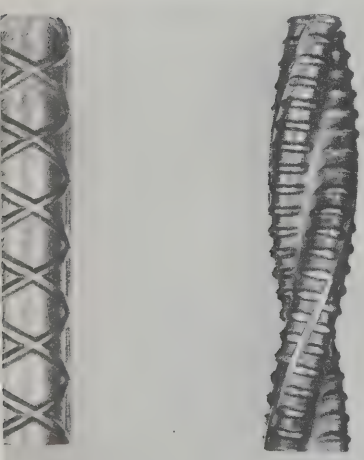
A STUDY of the effect of the magnitude of stresses in the reinforcement on the flexural behavior of reinforced concrete beams containing deformed steel bars having different stress-strain characteristics and different yield strengths has been conducted recently at the Bureau under sponsorship of the Committee on Reinforced Concrete Research of the American Iron and Steel Institute.[1] In some beams the longitudinal reinforcement was subjected to stresses in excess of 100,000 psi.

The results should provide technical data needed by code-writing bodies to formulate safe design practices for concrete structures containing high-strength reinforcement. Economies may thus become possible through use of smaller quantities of higher-strength steel. The study, which involved 12 reinforced concrete beams, was conducted by R. G. Mathey and D. Watstein.

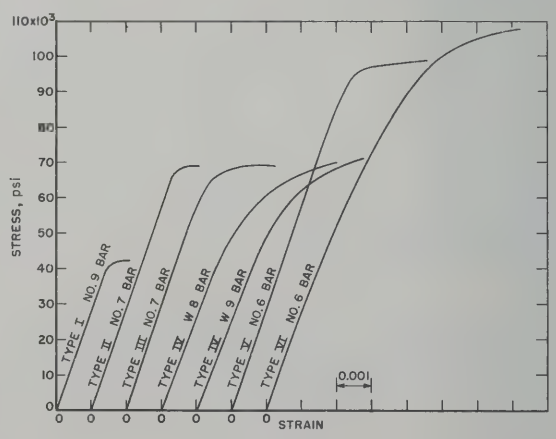
The nominal yield strengths of the reinforcement in the beams tested ranged from 40,000 to 100,000 psi. The higher yield strengths contrasted with the stress limit of 20,000 psi allowed in current building codes.

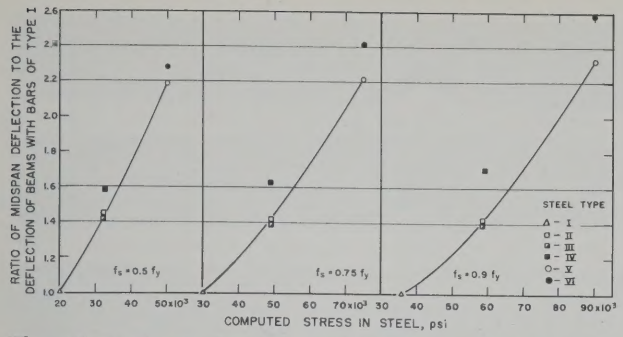
Manufacturers have long been able to produce steel with strengths greater than those of the steels used to establish an allowable stress of 20,000 psi. In some countries where steel is less plentiful than in the United States, the use of smaller quantities of stronger steel reinforcement has become customary. However, there is some concern in this country about the effect of a significant increase of the allowable stress in the reinforcement on cracking, deflection, and resistance to shear and bond stresses. The work described below is the first phase of a long-range study to supply the needed information.

The general purposes of the current investigation have been to determine to what extent higher steel stresses affect the resisting moment, width of cracks, strain in the concrete and steel, deflection, and the manner of failure of beams in which high-yield-strength reinforcement of smaller cross sectional area was substituted for intermediate grade deformed bars. The tests have produced data on the rigidity of beams with different types of reinforcement. They have indicated how short-term deflections can be computed by taking into



Left: Types of deformed steel bars used at the Bureau to reinforce concrete beams studied for the effect of magnitude of steel stresses on flexural behavior. The twisted bar on the right was designated as the Type IV bar. The other five types of bars had deformations as shown by the bar on the left. Right: Graph shows how stress-strain characteristics varied from linear with well-defined yield points to curvilinear, the latter observed with gradually yielding steel bars. (Numbers and letters after the type refer to sizes of bars.)





The effect of magnitude of steel stress on the midspan deflection is shown in this graph. The graph presents relative deflection values for computed steel stresses equal to 50, 75, and 90 percent of the nominal yield strengths of the bars. For the purpose of direct comparison, the deflections in beams containing 2.55 percent reinforcement (Type I bars) are taken as unity. The points representing bars having approximately linear stress-strain characteristics (Types I, II, III, and V) are connected by a line faired through the points. Beams with gradually yielding steels IV and VI are off this line, because they showed a more rapid increase in deflection with increasing stress.

account the elastic properties of both steel and concrete at various stresses.

Description of Specimens

The 12 reinforced concrete beams tested were alike in all respects except for the amount and kind of tensile reinforcement in each beam. The beams had cross sections of 6 by 15 in. and an effective depth of 12.8 in. They were 13 ft long, and were tested over a span of 10 ft.

Six types of deformed bars (Types I through VI) which differed both in their yield strengths and stress-strain characteristics were used as tensile reinforcement. Two beams with each type of reinforcement were tested. All the bars were conventional round reinforcing bars with diamond-shaped deformations except Type IV, which were cold twisted ribbed bars with dumbbell-shaped cross sections.

The amount of tensile reinforcement in the beams was proportioned inversely to the yield strength, thus providing approximately equal resistance to yielding under tensile forces. This was accomplished by substituting higher-yield-strength bars of smaller diameter, bar for bar. Thus, at a given applied bending moment, the stresses in the steel reinforcing bars were nearly proportional to the yield strength of the steel.

Testing Methods

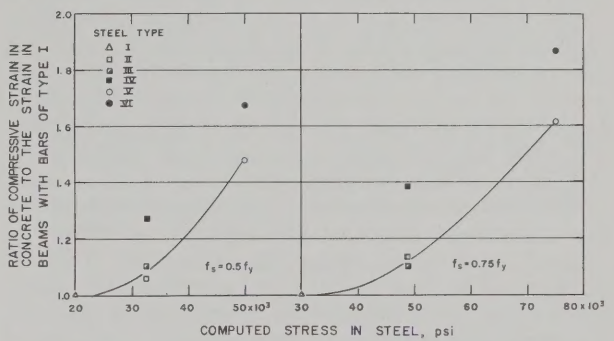
The beams were tested as simply supported beams in a 600,000-lb-capacity hydraulic machine. To facilitate the placement and reading of Tuckerman optical strain gages on the tensile faces of the beams, the beams were placed in the testing machine in an inverted position.

The width of cracks was measured with the 11 Tuckerman gages arranged in two rows located at equal distances from the longitudinal center line of each beam. Deflections at the center of span were measured with 0.001-in. dial gages attached to aluminum bars whose ends were supported at the sides of the beams under the concentrated loads. Strains in the tensile reinforcement at midspan were measured with bonded-wire electrical-resistance strain gages attached at diametrically opposite points at midplane of the longitudinal bars. The compressive strains in the concrete were measured with the same kind of gages.

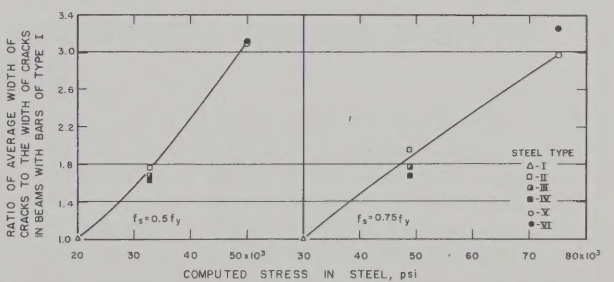
Results of Tests

The test results showed that the stress-strain characteristics varied from linear with well-defined yield points to curvilinear, obtained with gradually yielding steel bars.

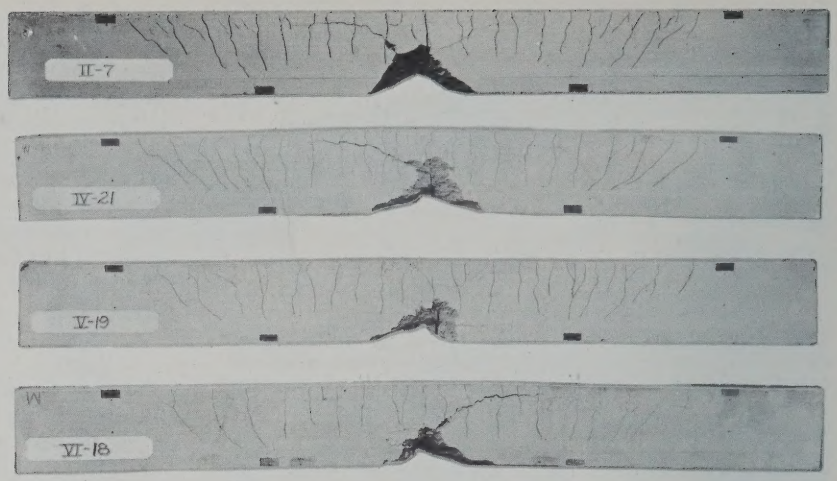
In the study, the comparative values of deflections, compressive strain in the concrete, and widths of cracks were reported with the values observed in the control beams containing Type I bars taken as unity. These Type I bars are inter-



Comparison of compressive strains in beams with computed steel stresses equal to 50 and 75 percent of the nominal yield strengths. (Values observed in Type I beams taken as unity.) The curves connect points representing bars (Types I, II, III, and V) having fairly linear stress-strain characteristics. The gradually yielding steels (Types IV and VI) are off the line of the curve.



Comparison of the average widths of cracks in beams reinforced with different types of deformed steel bars. (Crack widths in Type I beams taken as unity.) The comparisons are for computed steel stresses equal to 50 and 75 percent of the nominal yield strengths of the bars. Although the curves were faired through points representing bars having fairly linear stress-strain characteristics (Types I, II, III, and V), the remaining points, representing the gradually yielding steel bars (Types IV and VI), did not depart substantially from these curves. In fact, the effect of increasing steel stresses on widths of cracks was nearly the same for steels of all types.



Typical reinforced concrete beams after failure in flexure.

mediate grade steel bars of the type currently used in construction. Data were presented as functions of computed stresses in the steel bars, with ratios of stresses in the highest yield-strength bars ranging up to 2.5 times that in the control beams.

For stress ratios of 2.5, the ratios of deflections to those in beams with Type I bars were about 2.3 for the beams with bars having a linear stress-strain characteristic (Type V bars). However, beams with gradually yielding steel bars (Types IV and VI) showed a more rapid increase in deflection with increasing stress.

The ratios of observed compressive strains in the outermost fibers of the concrete to those in control specimens also fell into two distinct groups. For bars with linear stress-strain characteristics, the strain ratios ranged up to 1.6, and for gradually yielding steels up to 1.9.

The effect of increasing the steel stresses on width of cracks was nearly the same for bars of all types. Thus, at computed stresses equal to 0.5 of the yield strength in all cases, the maximum ratio of crack width to that in the control beams was 3.1, and it varied from 3.0 to 3.2 for stresses equal to 0.75 of the unit strength.

The ultimate resistance of the beams to bending was not appreciably affected by the tensile properties of the longitudinal reinforcement proportioned so as to have a constant total resistance to tensile forces. All beams failed at approximately the same load. However, beams containing the steel bars with a nominal yield strength of 100,000 psi failed either in compression or simultaneously in tension and compression, while all other beams failed in tension.

[1] *For further details, see* Effect of tensile properties of reinforcement on the flexural characteristics of beams, *by Robert G. Mathey* and *David Watstein, J. Am. Concrete Inst.* **31,** *No. 12, 1253 (June 1960).*

Announcement of New Publication

STANDARDIZATION ACTIVITIES IN THE UNITED STATES—A DESCRIPTIVE DIRECTORY

Standardization is the basis of modern industry. The Nation's achievements in technology—particularly in mass production and automation—are due in no small measure to the standards and good measurement practices established and disseminated by the many groups concerned with standardization.

Standardization Activities in the United States provides a descriptive inventory of the work and objectives of 350 organizations, both public and private, involved in standardization activities. Organizations are listed alphabetically with a brief description of the standardization area and accomplishments of each group.

A comprehensive index covers almost all widely known product areas—textiles, paper, leather, ceramics, plastics, electrical equipment, rubber, cement, etc.—and lists the organizations in each field. Not only products are standardized, but also materials, methods, techniques, sizes, nomenclature, services, and other areas.

Standardization Activities in the United States—A Descriptive Directory, by Sherman F. Booth, National Bureau of Standards Miscellaneous Publication 230, issued August 1, 1960, 210 pages, $1.75. (Order from Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.).

Publications of the National Bureau of Standards

Periodicals

Technical News Bulletin, Volume 44, No. 9, September 1960. 15 cents. Annual subscription: $1.50, 75 cents additional for foreign mailing. Available on a 1-, 2-, 3-year subscription basis.

Basic Radio Propagation Predictions for December 1960. Three months in advance. CRPL–D193, issued September 1960. 15 cents. Annual subscription $1.50, 50 cents additional for foreign mailing. Available on a 1-, 2-, 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.

Section D. Radio Propagation. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

Section A, Physics and Chemistry, Volume 64A, No. 5, September–October 1960.

Infrared spectrum of hydrobromic acid, E. K. Plyler.

Determination of the value of the farady with a silver-perchloric acid coulometer, D. N. Craig, J. I. Hoffman, C. A. Law, and W. J. Hamer.

Systems silver iodide-sodium iodide and silver iodide-potassium iodide, G. Burley and H. E. Kissinger.

Conformations of the pyranoid sugars. III. Infrared absorption spectra of some acetylated aldopyranosides, R. S. Tipson and H. S. Isbell.

Dissociation constant of 4-aminopyridinium ion in water from 0 to 50 °C and related thermodynamic quantities, R. G. Bates and H. B. Hetzer.

Tritium-labeled compounds VI. Alditols-1-*t* and alditols-2-*t*, H. L. Frush, H. S. Isbell, and A. J. Fatiadi.

Section D, Radio Propagation, Volume 64D, No. 5, September-October 1960.

ELF electric fields from thunderstorms, A. D. Watt.

Field strength measurements in fresh water, G. S. Saran and G. Held.

Electrical resistivity studies on the Athabasca Glacier, Alberta, Canada, G. V. Keller and F. C. Frischknecht.

Amplitude distribution for radio signals reflected by meteor trails, A. D. Wheelon.

Computation and measurement of the fading rate of moon-reflected UHF signals, S. J. Fricker, R. P. Ingalls, W. C. Mason, M. L. Stone, and D. W. Swift.

On the theory of wave propagation through a concentrically stratified troposphere with a smooth profile, H. Bremmer.

Polarization and depression-angle dependence of radar terrain return, I. Katz and L. M. Spetner.

Methods of predicting the atmospheric bending of radio rays, B. R. Bean, G. D. Thayer, and B. A. Cahoon.

Loss in channel capacity resulting from starting delay in meteor-burst communication, G. R. Sugar.

Elementary considerations of the effects of multipath propagation in meteor-burst communication, G. R. Sugar, R. J. Carpenter, and G. R. Ochs.

Use of logarithmic frequency spacing in ionogram analysis, G. A. M. King.

Guiding of whistlers in a homogeneous medium, R. L. Smith.

Propagation of microwaves through a magneto-plasma, and a possible method for determining the electron velocity distributions, A. L. Cullen.

On electromagnetic radiation in magneto-ionic media, H. Kogelnik.

Radiation and admittance of an insulated slotted-sphere antenna surrounded by a strongly ionized plasma sheath, J. W. Marini.

A contribution to the theory of corrugated guides, G. Piefke.

High-gain, very low side-lobe antenna with capability for beam slewing, A. C. Wilson.

Shielding of transient electromagnetic signals by a thin conducting sheet, N. R. Zitron.

Cylindrical antenna theory, R. H. Duncan and F. A. Hinchey.

Nonperiodicals

Stabilization of free radicals at low temperatures, edited by A. M. Bass and H. P. Broida. NBS Mono. 12 (1960) $1.50.

Protection against radiations from sealed gamma sources. NBS Handb. 73 (1960) (Supersedes H54) 30 cents.

Standardization activities in the United States—A descriptive directory, S. F. Booth. NBS Misc. Publ. 230 (1960) (Supersedes M169) $1.75.

Hydraulic Research in the United States, 1960, H. K. Middleton. NBS Misc. Publ. 231 (1960) $1.00.

Alphabetical index to tables of chemical kinetics. Homogeneous reactions. Supplement 2 to NBS Circ. 510 (1960) 35 cents.

Technical Notes

The following Technical Notes are available from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. (Order by PB number.)

A survey and bibliography of recent research in the propagation of VLF radio waves, J. R. Wait. NBS TN58 (PB161559) (1960) 75 cents.

Amplitude and phase of the low- and very low-radiofrequency ground wave, J. R. Johler, L. C. Walters, and C. M. Lilley. NBS TN60 (PB161561) (1960) 75 cents.

Single scattered neutrons from an isotropic point source, E. R. Mosburg, Jr., and W. M. Murphey. NBS TN63 (PB161564) (1960) 50 cents.

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Microwave spectrum of trans-crotononitrile, V. W. Laurie, J. Chem. Phys. 32, No. 5, 1,588 (1960).

Tropospheric fields and their long-term variability as reported by TASO, P. L. Rice, Proc. IRE 48, 1,021 (1960).

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Effect of tensile properties of reinforcement on the flexural characteristics of beams, R. G. Mathey and D. Watstein, J. Am. Concrete Inst. 31, No. 12, 1,253 (1960).

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The intensity of [OI] 5577 in the subauroral region as a function of magnetic activity, F. E. Roach, J. Geophys. Research 65, No. 5, 1,495 (1960).

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Publications (*Continued*)

Interpolation of platinum resistance thermometers, 20° to 273.15° K, R. J. Corruccini, Rev. Sci. Instr. **31**, No. 6, 637 (June 1960).

Radiation from a slot on a large corrugated cylinder, J. R. Wait and A. M. Conda, Electromagnetic Wave Propagation, Proc. Intern. Conf. Propagation of Radio Waves, Liege, Belgium, 1958, p. 103 (Academic Press Inc., New York, N.Y., 1960).

Low-temperature transport properties of commercial metals and alloys. IV. Reactor grade Be, Mo, and W, R. L. Powell, J. L. Harding, and E. F. Gibson, J. Appl. Phys. **31**, No. 7, 1221 (July 1960).

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Post office mechanization, B. M. Levin, M. C. Stark, and P. C. Tosini, Proc. Information Processing and Retrieval, Am. Inst. Elec. Engrs. General Meeting, June 19–24, 1960, Atlantic City, N.J., Am. Inst. Elec. Engrs. Paper CP60–937 (1960).

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Transfer of liquid hydrogen through uninsulated lines, R. J. Richards, W. G. Steward, and R. B. Jacobs, Proc. 1959 Cryogenic Engr. Conf. **5**, Advances in Cryogenic Engineering, p. 103 (Plenum Press, New York, N.Y. 1960).

Bounds on the dissipation of energy in steady flow of a viscous incompressible fluid around a body rotating within a finite region, E. A. Kearsley, Arch. Rational Mech. and Analysis **5**, No. 4, 347 (1960).

Publications for which a price is indicated (except for Technical Notes) are available only from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (foreign postage, one-fourth additional). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

URSI–IRE Meeting To Be Held December 12–14

The national meeting of the International Scientific Radio Union and the Institute of Radio Engineers (URSI–IRE) will be held at the Bureau's Boulder Laboratories from December 12 to 14. Although a worldwide meeting of URSI was held at Boulder in 1957, this will be the first time that the annual fall conference of the two organizations has met there. Alan Shapley, Chief of Liaison and Program Development for the Central Radio Propagation Laboratory at Boulder, is in charge of the local arrangements.

URSI investigates all scientific aspects of radio energy including radio standards, radio astronomy, radio noise, and the transmission of radio waves through the earth's atmosphere. It stimulates international cooperation in the scientific study of radio and seeks to attain common methods and standards of radio measurement throughout the world.

When the entire world must be used as a laboratory—as in radio astronomy and in studies of the earth's atmosphere—URSI plays a particularly important role. For example, the initial concept of the International Geophysical Year of 1957–58 was born within the United States URSI organization.

While the field of URSI is essentially science and research, IRE deals primarily with engineering and development of particular techniques. URSI is essentially international while IRE is primarily national, although the work of both is closely related and there is continual cooperation between the two.

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